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## (54) FUEL CELL

(71) We, INSTITUT FRANCAIS DU PETROLE, a body corporate organised and existing under the laws of France, of 4 avenue de Bois-Preau, 92502 Rueil-Malmaison, France, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:–

The present invention relates to fuel cells.

A fuel cell usually comprises a block wherein electrodes delimit a plurality of chambers, some of these chambers containing a liquid or solid electrolyte, such as a solution of potassium hydroxide KOH, others being fed with a liquid fuel such as methanol or a gaseous fuel such as hydrogen gas of appropriate purity, and the remaining chambers being fed with a liquid or gaseous comburent (i.e. combustion-sustaining fluid) such as pure oxygen or air.

When the fuel cell is in operation and delivering electric power to a load circuit, the pressure in the various chambers is maintained at a determined value, either close to atmospheric pressure in one (most common) type of fuel cells, or much greater than atmospheric pressure in another, so-called high pressure, type of fuel cells.

When no electric power is delivered by the fuel cell to a load circuit, a certain residual rate of consumption of the reactants nevertheless occurs, owing to 'electrochemical short-circuit' within the fuel cell. In order to reduce this consumption, it is desirable to discontinue the feeding of reactants when the fuel cell is off duty.

When this is done, only the reactants contained in the fuel cell block at the time of switch-off can be consumed by electrochemical short-circuit. However, this consumption results in a pressure decrease in the chambers and the pressure differences which may appear between two chambers separated by an electrode can result in a deterioration of the fuel cell be deformation of the electrodes.

Up to now different techniques have been used to obviate this drawback:–

(a) when the fuel cell is out of operation for only a short time interval, the feeding of the fuel cell with reactants may be not interrupted, and reactants continue to be consumed by electrochemical short-circuit within the fuel cell.

(b) when the fuel cell is out of operation for longer periods, the feeding of the fuel cell block may be interrupted and after the fuel and/or comburent chambers have been isolated, at least one liquid or gaseous auxiliary fluid at a determined pressure is introduced thereinto, this auxiliary fluid producing no electrochemical reactions.

Such a method has the drawback of requiring a special container to store a relatively large quantity of auxiliary fluid, thus increasing the weight and volume of the fuel assembly. Moreover the operator must perform additional operations to substitute the auxiliary fluid for the reactants and vice-versa, depending on whether the fuel cell is or not in operation.

It is desirable to provide a fuel cell wherein the pressure in at least some of the reactant chambers is automatically prevented from failing unduly, without requiring any intervention of the operator when the fuel cell is off duty.

According to the invention there is provided a fuel cell comprising a cell block having therein electrodes delimiting at least one first chamber for containing a comburent, and either at least one second chamber for containing a fuel and at least one third chamber for containing an electrolyte or at least one second chamber for containing a fuel-electrolyte mixture; inlet and outlet lines communicating with the chambers for supplying comburent to the first chamber(s)

and for supplying either fuel to the second chamber(s) and electrolyte to the third chamber(s) or fuel-electrolyte mixture to the second chamber(s); and, for at least one of the first and second chambers, respective closure valves provided in a siad inlet line and a said outlet line communicating with said chamber and a reservoir communicating with the inlet or outlet line of said chamber, at a oiubt if said line intermediate the closure valve provided in said line and the fuel cell block, in such a manner that, when the fuel cell is in use, the volume of the reservoir is entirely filled with comburent, fuel or fuel/electrolyte mixture, the pressure compensation reservoir being sealed from contact with the atmosphere and having a fluid-tight movable wall or walls allowing the volume of the reservoir to change in response to changes in the volume of fluid contained therein.

Suitably, when the fuel cell is used for generating electricity with intermittent shutdown by closure of said closure valves for a period between two periods of operation, the pressure compensation reservoir can have a maximum volume at least equal to the volume of fluid consumed in the fuel cell block during the period of closure of said closure valves. Suitably, the reservoir has a flexible wall or wall portion allowing the volume of the reservoir to change in response to changes in the volume of fluid contained therein.

In a fuel cell which is suitable for a method of use wherein said chamber or chambers are supplied with a fluid which comprises an electrochemically active constituent in a proportion C% by volume and an electrochemically inert constituent in a proportion (100-C)% by volume, the pressure compensation reservoir suitably has a maximum volume of at least $(V_c x C/(100-C))$ where $V_c$ is the volume of said chamber or chambers of said cell block.

In liquid fuel cells embodying the invention, the pressure compensation reservoir preferably communicates with the inlet or outlet line of a chamber for containing liquid fuel and is disposed at a level higher than the cell block when the cell is oriented for use.

A protective housing can be disposed around the sealed variable-volume reservoir. The outside of the reservoir can be in contact with the atmosphere, or alternatively the housing can seal the pressure compensation reservoir from contact with the atmosphere and means for exerting a pressure higher than atmospheric pressure on said compensation reservoir can be disposed within said housing. Either a gas or a spring can for example be used to exert the pressure.

The invention is described in detail in the following description given by way of example only of particular, preferred embodiments thereof, illustrated by the accompanying drawings, wherein:–

Figure 1 is a diagram showing an embodiment of a fuel cell according to the invention; and

Figures 2 to 5 diagrammatically illustrate different embodiments of the pressure compensation reservoir of the embodiment of Figure 1.

Referring to Figure 1, a fuel cell comprises a block 1 wherein electrodes delimit a plurality of chambers (not shown). In some types of fuel cell the electrodes delimit chambers fed with a mixture of fuel and electrolyte and chambers receiving a comburent.

However, in the embodiment of Figure 1, the electrodes delimit three kinds of separate chambers, comprising electrolyte chambers fed exclusively with electrolyte, fuel chambers fed with fuel and comburent chambers bed with comburent. In alternative embodiments of the invention the arrangement may be as described above, i.e. some chambers may receive mixtures.

The fuel cell block 1 is provided with inlet ports 2, 3 and 4 and outlet ports 5,6 and 7 connected to pipes of different circuit feeding the fuel cell respectively with electrolyte, fuel and comburent.

Ports 2 and 5 are respectively connected to pipes 8 and 9 diagrammatically shown by dotted lines and forming part of a circuit feeding the fuel cell with electrolyte, for example, potassium hydroxide, KOH. Ports 3 and 6 are respectively connected to pipes 10 and 11, diagrammatically illustrated by dashed lines and forming part of a fuel feeding circuit of the cell block.

The circuits feeding the fuel cell block 1 respectively with electrolyte and fuel are not shown in the drawing, but it is understood that each of them comprises all the means which are conventionally used to provide for a correct feeding of the fuel cell, for example, a circulation pump, a device for regulating the temperature of the fluid feeding the fuel cell block and so on. All these devices are well known to those skilledin the art and therefore need not be further described in detail.

Ports 4 and 7 of the fuel cell block communicate with the comburent feeding circuit. In the embodiment of the invention illustrated by Figure 1 port 7 is directly connected to pipe 12 of the comburent feeding circuit shown in solid line of the drawing. Port 4 is connected to pipe 13 of the comburent feeding circuit, through a device designated as a whole by reference numeral 14.

Device 14 comprises a pressure compensation reservoir 19 having a maximum volume $V_m$, delimited by a wall having at least

one deformable portion 20 which transmits the pressure applied on its external surface to the fluid contained therein. The reservoir communicates with the inlet port 4 and with pipe 13 through a pipe 21.

The circuit feeding the fuel cell with comburent comprises closure valves 15 and 16 for the comburent inlet and outlet ports of the fuel cell block, and also comprises a pump 17 providing for the circulation of the comburent in the direction indicated by the arrows, and means diagrammatically shown at 18, for conditioning the comburent, which in this example is a decarbonator, the comburent being air.

However, in other embodiments, for example those employing other comburents, condition 18 may carry out other treatments.

The operation of the fuel cell is as follows. When the fuel cell is connected to an electrical load circuit (not shown), the fuel cell block is simultaneously fed with electrolyte, comburent and fuel by the feeding circuits. The valves 15 and 16 are open and fuel fills reservoir 19, whose volume is then maximum, shown as a solid line in Figure 1. The comburent in reservoir 19 is substantially at the same pressure as the comburent in the fuel cell block.

When the fuel cell is off duty, valves 15 and 16 are closed. The fuel cell block is thus no longer fed with comburent by the feeding circuit, by the fuel supply is continued.

Owing to the phenomenon of electrochemical short-circuit, fuel and comburent consumption occurs, resulting in a decrease of the comburent pressure in the comburent chambers. This pressure decrease is transmitted to the inside of reservoir 19 which permanently communicates with port 4. As a result of the pressure applied to the external surface of the wall 20, reservoir 19 is deformed, thereby diminishing in volume (position shown as dashed line in Figure 1). Consequently the comburent pressure within the reservoir 19 and thus within the fuel cell block is maintained at a substantially constant value for which there is no risk of deformation of the electrodes. The pressure applied to the external surface of reservoir 19 is substantially equal to thecomburent pressure in block 1 during the periods of operation of the fuel cell.

Reservoir 19 is so chosen that its maximum volume $V_m$ is at least equal to the volume of the comburent consumed when the fuel cell is off duty.

In the illustrated embodiment device 14 is connected to the inlet port 4, but it would be possible, without departing from the scope of the present invention, to connect device 14 to the outlet port.

When the fuel chambers are separate from the electrolyte chambers, as in the Figure 1 embodiment, another device similar to device 14 can be connected to the fuel inlet port 2 or the corresponding outlet port, the fuel feeding circuit being then provided with valves similar to valves 15 and 16.

In the case of fuel cells using air as comburent, reservoir 19 should have a maximum volume of at least 25% of the volume formed by the chambers of the block which are fed with air. The volume of any pipe work in communication therewith is of course included in making the calculation of the comburent chamber volume.

Whenever the fuel cell is off duty and all the oxygen of air has been consumed because of the electrochemical short circuit, the comburent chambers are automatically filled with the residual nitrogen, which is an inert gas producing no electrochemical reaction in the fuel cell.

The consumption of fuel and comburent then becomes equal to zero and the fuel cell can be maintained in this state indefinitely without requiring any interruption of the fuel supply.

More generally, when there is introduced into the fuel cell block a mixture of fluids comprising a fluid which does not produce any electrochemical reaction and a fluid which is a reactant in such an electrochemical reaction, the tank 19 will have a maximum volume $V_M$ at least equal to $V_M = V_c \times \frac{C}{1-C}$, wherein $V_c$ is the overall volume of the chambers receiving this mixture of fluids and C a coefficient equal to the proportion by volume of this reactant in the mixture introduced into the fuel cell.

When the comburent is air, $V_M$ is suitably at least 25% of $V_c$.

Figure 2 shows a diagrammatic cross section of one alternative version of the device 14 of Figure 1, which can be used for reactants feeding the fuel cell block under near-atmospheric pressure.

Reservoir 19 comprises a fluid-tight, flexible membrane 20, made for example of a thin layer of a material having a high flexibility, for example synthetic or natural rubber, or resilient plastics materials. Reservoir 19 communicates via pipe 21, on the one hand, with inlet port 4 of the fuel cell block 1 for the comburent and on the other hand, with pipe 13 of the circuit feeding the fuel cell block with comburent.

In other embodiments the device may be in the comburent circuit or not.

Reservoir 19 is placed in a rigid housing 22 for protection of the membrane 20. The housing 22 is provided with openings 23 to allow passage of the ambient air, whose pressure (the atmospheric pressure in this embodiment) is in contant with the external surface of wall 20.

Figure 3 shows an alternative embodiment of the device 14 illustrated by Figure

2, wherein reservoir 19 is connected to opening 4 through pipe 21*b* and to pipe 13 through pipe 21*a*.

Figure 4 illustrates an alternative form of the device 14 illustrated in Figure 3, for use with a fuel cell fed with liquid reactant.

In the embodiment of Figure 4, reservoir 19 is vertical and comprises a flexible membrane 20, which avoids any pollution of the liquid by ambient air. The reservoir is supported in a housing 22.

When liquid reactants are used, reservoir 19 will be placed at a higher level than the fuel cell block when the fuel cell block is oriented for use.

The devices 14 shown in Figures 2 to 4 may, with adaptation, be used in high pressure fuel cells. Thus, for example, in the absence of openings 23 of the casing (Figures 2–5) it is possible to introduce therein a gas at a pressure close to the pressure prevailing within the fuel cell when under operation. It is also possible to use an elastic membrane 20, delimiting such a volume, arranged so that at the minimum volume of reservoir 19, when the fuel cell is off duty membrane 20 is stretched and maintains the fluid in the reservoir 19 at a pressure at least equal to some desired value.

Figure 5 shows another device 14 in which the pressure in reservoir 19 results from the application of a force to the external surface of wall 20 through a spring 24.

WHAT WE CLAIM IS:–

1. A fuel cell comprising a cell block having therein electrodes delimiting at least one first chamber for containing a comburent, and either at least one second chamber for containing a fuel and at least one third chamber for containing an electrolyte or at least one second chamber for containing a fuel-electrolyte mixture; inlet and outlet lines communicating with the chambers for supplying comburent to the first chamber(s) and for supplying either fuel to the second chamber(s) and electrolyte to the third chamber(s) or fuel-electrolyte mixture to second chamber(s); and, for at least one of the first and second chambers, respective closure valves provided in a said inlet line and a said outlet line communicating with said chamber and a pressure compensation reservoir communicating with the inlet or outlet line of said chamber, at a point of said line intermediate the closure valve provided in said line and the fuel cell block, in such a manner that, when the fuel cell is in use, the volume of the reservoir is entirely filled with comburent, fuel or fuel/electrolyte mixture, the pressure compensation reservoir being sealed from contact with the atmosphere and having a fluid-tight movable wall or walls allowing the volume of the reservoir to change in response to changes in the volume of fluid contained therein.

2. A fuel cell according to claim 1, which has been used for generating electricity with intermittent shutdown by closure of said closure valves for a period between two periods of operation, wherein said pressure compensation reservoir has a maximum volume at least equal to the volume of fluid consumed in the fuel cell block during the period of closure of said closure valves.

3. A fuel cell according to claim 1, which is suitable for a method of use wherein said chamber or chambers are supplied with a fluid which comprises an electrochemically active constitusnt in a proportion C% by volume and an electromechanically inert constituent in a proportion (100−C)% by volume, and wherein the compensation reservoir has a maximum volume of at least ($V_c \times C/(100-C)$) where $V_c$ is the volume of said chamber or chambers of said cell block.

4. A fuel cell according to claim 1, 2 or 3, suitable for use with gaseous fuel or comburent and wherein the pressure compensation reservoir communicates with the inlet or outlet line of a chamber for containing said gaseous fuel or comburent.

5. A fuel cell according to claims 3 and 4, suitable for use with air as comburent, and wherein the maximum volume of the compensation reservoir is at least 25% of $V_c$.

6. A fuel cell according to claim 1, 2 or 3, being a liquid fuel cell, in which the or each pressure compensation reservoir communicates with the inlet or outlet line of a chamber for containing liquid fuel and is disposed at a level higher than the cell block when the cell is oriented for use.

7. A fuel cell according to any preceding claim, wherein the reservoir has a flexible wall or wall portion allowing the volume of the reservoir to change in response to changes in the volume of fluid contained therein.

8. A fuel cell according to claim 7, wherein at least a portion of the wall or walls of said compensation reservoir is made of a membrane of natural or synthetic rubber or other resilient plastics material.

9. A fuel cell according to claim 4, or any claim dependent thereon, wherein a protective housing surrounds said compensation reservoir.

10. A fuel cell according to claim 4 or any claim dependent thereon, being a fuel cell designed for operation at about atmospheric pressure, wherein the outside of said compensation reservoir is in contact with the atmosphere.

11. A fuel cell according to claim 9, wherein said housing seals said pressure compensation reservoir for contact with the atmosphere, and wherein means for exerting a pressure higher than atmospheric pressure on said compensation reservoir is disposed

within said housing.

12. A fuel cell according to claim 11, wherein said pressure exerting means comprise a gas.

13. A fuel cell according to claim 11, wherein said pressure exerting means comprises a spring.

14. A fuel cell according to claim 7 or any claim dependent thereon, wherein the or each said reservoir is delimited by a flexible elastic wall which is maintained stretched regardless of volume variation of the reservoir.

15. A fuel cell substantially as hereinbefore described with reference to Figure 1 or Figure 1 as modified by any one of Figures 2 to 5 of the accompanying drawings.

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1534015 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG.1

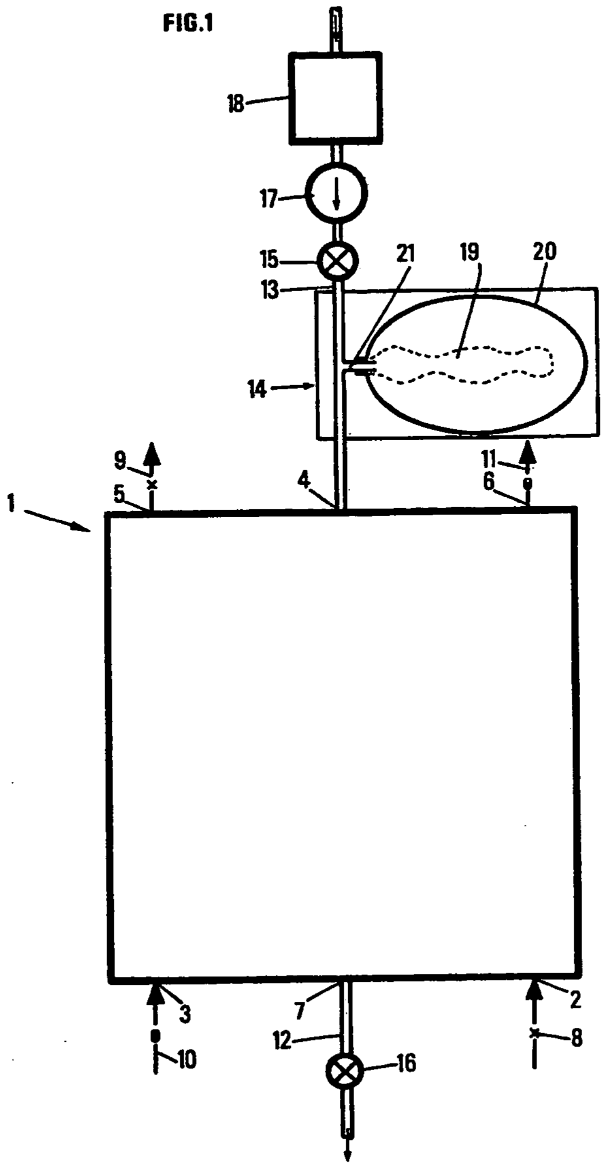

FIG.2

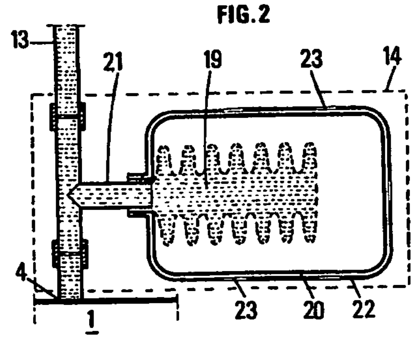


FIG.3

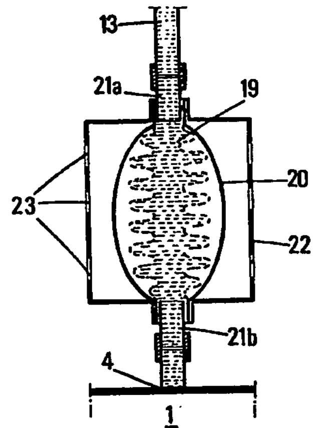


FIG.4

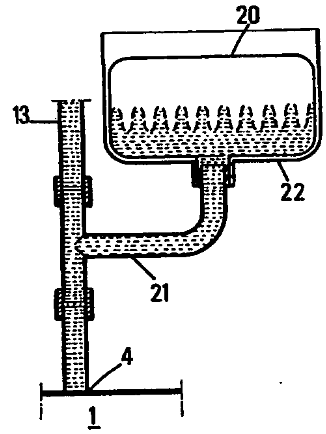


FIG.5